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Excitation of Lightweight Steel Hollow Spheres by Means of Pulsed Electromagnetic Field

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Abstract

A technique of accelerated movement of metallic element by means of a pulsed electromagnetic field is sufficiently known. Despite of that, a behavior of lightweight steel hollow spheres in pulsed electromagnetic fields is not fully explored. A particular emphasis of current study is a modeling of lightweight steel hollow spheres behavior in pulsed electromagnetic field. This phenomenon can be exploited for vibrations damping in granular dampers, where dissipation of mechanical energy via particle collisions occurs.

In current paper some prospects of pulsed electromagnetic field usage for lightweight steel hollow spheres excitation and practical applications in vibration control are suggested.

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Keywords: Pulsed electromagnetic field; Hollow spheres; Damping; Modeling

1. Introduction

A technique of accelerated movement of the metal element by means of a pulsed electromagnetic field is widely known. It is used, for example, for moving the punch during the pressing of powder materials[1] , the deformation of metal pipes and casings[2], parts assembling[3], and many other processing operations. In papers[4,5] characteristics and specific perspectives of ferromagnetic powder displacement for the purpose of transportation are reviewed.

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In recent years, there is evidently strong interest in lightweight steel hollow spheres[6] synthesis and applications[7,8]. A particular interest is the study of the behaviour of LSHS as a model material for vibrations damping in granular dampers[9], which are based on the dissipation of mechanical energy via particle collisions[10]. At the same time, a behaviour of LSHS in pulsed electromagnetic fields is not fully explored. The current article introduces prospects of PEMF usage for LSHS excitation and identifies some practical applications in mechanics and vibration control.

2. Theoretical background

The electromagnetic (Lorenz forces) and mechanical (particles collision) processes have a strong influence on LSHS movement in PEMF. In general, electromagnetic force on the displaced materials (i.e. LSHS) is a gradient of the accumulated energy in air gap and materials to be moved, thus, electromagnetic force depends on current in the coil and the inductance gradient[11] (1):

$$F = \frac{\delta E(i,x)}{\delta x} \qquad (1)$$

The equation of a LSHS single sphere mass motion can be expressed as (2):

$$m\ddot{x} = F_{magnetic} - F_{damping} - F_{extra} \qquad (2)$$

Here, F_{extra} is additional forces, such as friction and gravitational forces.

3. Experimental part

The technique features the use of capacitor banks with stored energy from 1 up to 100 kJ (see Fig. 1). The discharge of capacitors to the coil (working tool) initiates short pulsed electromagnetic field with intensity of 50-200 A/m and duration of few milliseconds (see Fig. 2).

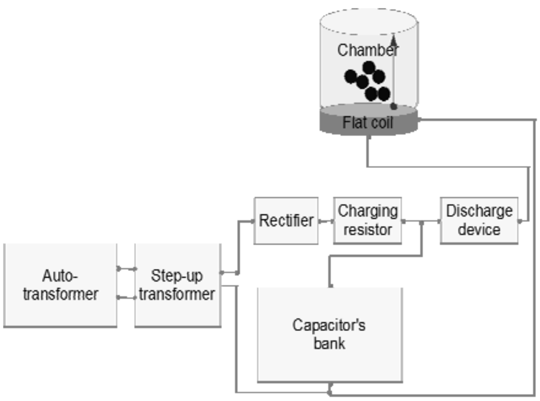

Fig. 1. Schematics of electromagnetic system used for LSHS research.

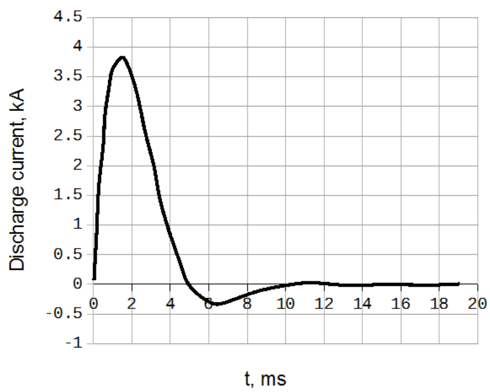

Fig. 2. A typical impulse shape generated by impulse current source.

The interaction between PEMF and electrically conductive element has to provoke a displacement of ECE. There are two main results of such interaction - repulsion or attraction between ECE and coil. This depends on the ECE material properties, electromagnetic field parameters, and relative arrangement of the coil and ECE.

Experimental rig based on equipment EMC-5[12] has been used for trials. Test material's characteristics are presented in Table 1.